Lead Investigator: Michael Bunds, Department of Earth Science, Utah Valley State College

Project Summary

This proposal requests a summer stipend to support a project that will initiate long-term high-precision monitoring of land surface movements in the Utah Valley area. The monitoring data will provide tests of hypotheses related to tectonics, landslides and groundwater level changes in Utah Valley. This project will provide numerous opportunities for undergraduates to participate in scientifically significant research and to acquire skills widely applied by geoscience professionals and academics. The initial cycle of work, for which this proposal seeks funding, will focus on identifying locations to be monitored, constructing permanent markers, and performing initial surveys of the markers. The project can thrive in the future with minor funding, or can be enlarged with external funding.

Scientific Background and Expected Research Results

The proposed project focuses on three important geologic processes that lead to land surface deformation: tectonic movements, landslides, and groundwater level changes. Each of these processes is of fundamental importance to human activity in Utah Valley and an active area of academic research. Measurement of the land surface displacements produced by these geologic phenomena will provide critical information on their underlying nature and presents a challenging and scientifically meaningful area of research ideal for undergraduates.

Tectonics:
Utah is a tectonically active area, as its mountains and earthquakes reveal. Horizontal extension across the basin and range has led to the formation of fault block mountain ranges such as the Wasatch and Lake Mountains, which have risen relative to the intervening valley along normal faults. Radiometric dating and analysis of inclusions of fluids in exhumed rocks indicate that the Wasatch mountains have risen about 10 to 15 km in the past 10 million years, and that the movement continues today. Other geologic evidence suggests that the vertical movement is episodic. At times the Wasatch fault has remained locked while far-field tectonic movements continued and elastic strain built up in the crust until it was released in large earthquakes. In contrast, evidence for the long term horizontal movements across Utah Valley and much of the basin and range is generally lacking or speculative. An active research program administered by the University of Utah is monitoring these movements across the Salt Lake Valley, but data are sparse in the Utah Valley area.

The proposed work will provide data on the current rate and distribution of movement in Utah Valley that will allow us to better understand the build-up of elastic deformation that may be released in a future large earthquake. The total energy released by an earthquake is fundamentally limited by the rate energy is stored as elastic strain in the crust adjacent to faults. If far field strain - for example between the Lake Mountains and Heber Valley - is rapid relative to movement on the Wasatch fault, then elastic strain energy is being stored in the crust adjacent to the fault. By measuring these movements, we will gather crucial information on tectonic and potentially seismogenic crustal deformation in the area. The measurements will also record the horizontal extension that fundamentally causes the vertical tectonics and earthquakes in the area, for which there currently is only sparse information. Our results will supplement the work being done at the University of Utah, and we will collaborate with them to build a model of the active regional tectonics throughout the Wasatch Front.

Landslides:
Mass-wasting, of which landslides are one type, on average causes the most economic loss of any geologic hazard in the U.S. Within and near Utah County there are numerous known active and potentially active landslides that threaten life and property. Commonly, landslides that have demonstrably moved in the past remain nearly static for many years before undergoing further major movements in response to external forcing, such as precipitation, snowmelt, or earthquakes. The proposed research work will utilize frequent, precision measurement of landslide movements to identify
potentially hazardous landslides and to improve our understanding of the response of landslides to external forcing.

Small landslide movements caused by minor external forcing can be a strong predictor of more hazardous and costly movements. More destructive slides tend to occur in response to relatively rare major forcing events, but are hypothesized to move small amounts - undetectable without high-precision measurement techniques - in response to minor forcing. In addition, measurement of small movements provides the necessary information to determine which external forces are most significant. Otherwise, data on movements only become available following relatively rare major events, too late to avoid loss of property or life. The Provo City Engineering Department has identified several potentially active landslides that may cause significant damage. We will work with Provo to study those slides that are of greatest concern.

**Groundwater:** Groundwater is an important resource in Utah and throughout the world. Monitoring its level in the ground and understanding its recharge areas, flow directions, and rate of supply are crucial to our successful utilization of this critical resource. The proposed project will invoke a novel approach to monitoring groundwater level (water table) changes. The approach utilizes vertical movement of the ground that occurs in response to changes in the water table level. As the water table rises, the fluid pressure in the ground increases, which causes the rock or sediment in which the water resides to expand. Thus, when the water table rises, so does the ground surface, and vice-versa. Presumably, this occurs beneath the UVSC campus. The proposed project will measure ground surface movements at three established wells near the campus wetlands so we can calibrate surface uplift to water table changes. This calibration will have the added benefit of constraining the elastic properties of the rock or sediment in which the groundwater resides, thereby enabling us to better understand local fluid flow and water table changes in terms of fluid fluxes.

**Project Activity Details and Timeline**

This proposal seeks funding for the first phase of work on this project. The project is expected to continue indefinitely. The first phase, which will be completed this summer, will involve identifying monitoring locations, designing and constructing permanent markers (benchmarks), and conducting initial surveys of the markers. We have already begun scouting potential sites, and selecting final sites will require several days of reconnaissance. Construction of benchmarks will begin in early May and is expected to be completed by early June. The initial surveys of the benchmarks will be completed by the end of June. The time required for data collection may be shortened if additional GPS equipment can be borrowed from colleagues at the University of Utah or Brigham Young University (preliminary contacts have indicated that this is a possibility). In total, approximately 8 weeks of work will be required to establish and survey an initial set of benchmarks for monitoring tectonic, landslide and water table changes in the Utah Valley area.

Future surveys, following establishment of the benchmarks, will be undertaken quarterly to annually, or in response to events such as earthquakes (for the tectonic and landslide aspects of the study) or heavy precipitation (for the landslide portion of the study) that may spur movement. These surveys can be completed with minimal funding supplied by the Department of Earth Science. Meaningful movements are expected to occur in the short term – especially in relation to landslides and groundwater – but longer-term data collection will provide the most scientifically meaningful data. Thus, we foresee this project continuing successfully for many years. Students will build a legacy of data, and through their scientific research will become connected to past and future participants in the study.

The tectonic measurements will require 8 to 12 benchmarks that will span the Wasatch fault. The benchmarks will be arrayed the length of Utah Valley, with half of the markers located within a few kilometers of the fault and the other half more than 15 km from the fault. Thus movements near and far-field relative to the fault will be captured. Probable locations are Rock Canyon, UVSC campus, Heber area, Lake Mountains, Squaw Peak Road, SANTAQUIN, SANTAQUIN Canyon and Payson Lakes area.

A number of active or potentially active landslides in the Provo area have been identified. One to several benchmarks will be required for each landslide. Vertical land surface movements related to water
table changes will initially be monitored on the UVSC campus wetlands area, where Daniel Horns of the Earth Science Department currently maintains 3 water wells.

**Undergraduate Research Participation**

Undergraduates will be involved with the project at every stage, from selection of benchmark sites, through construction and measurement of benchmarks, to analysis, interpretation and reporting of results. The project is an ideal educational opportunity for undergraduates because they will participate in experiment design, data collection, interpretation, and documentation and dissemination of results. Through their work on the project, students will gain specific skills such as operation of phase-differential GPS equipment, computer-based data reduction, writing, and public speaking. Experience with GPS equipment will be particularly beneficial to students who pursue careers as geoscience professionals.

A minimum of two to three undergraduates will participate in benchmark site selection, construction and the initial surveys this summer. We envision three types of involvement by undergraduate students: (1) Students paid through the work study program will provide regular assistance in installing benchmarks and collecting and compiling data; (2) interested students may sign up for GEOL 495R (Independent Study) and complete projects related to our efforts (e.g., analysis and interpretation of several month’s worth of data from an individual landslide); and (3) some of the data collection will be carried out by students in our Geologic Hazards and Structure and Tectonics classes as part of the regular course curricula. The students involved will gain insight into geologic processes, skills that are valuable in applied geologic work, and experience that will help them gain employment or admission to graduate programs.

**Dissemination of Research Results**

Undergraduates involved with the project will make oral presentations on campus, at local meetings of the Association of Engineering Geologists, at regional meetings of the Geological Society of America, and possibly at national meetings if funding is available. The lead investigator expects to produce and disseminate results of the scientific investigations through meetings and journals of the Geological Society of America and the American Geophysical Union. The project’s educational benefits will be documented in a paper for the Journal of Geoscience Education and participation in sessions on geoscience education at meetings of national geoscience organizations.

**Continuation of the Project**

This project is expected to be continued indefinitely. Once benchmarks are established, it will be possible to perform periodic re-surveys for minimal expense. However, the project would benefit scientifically and educationally from expansion, and there are several possible sources of additional, external funds. During the upcoming academic year, the Department of Earth Science intends to apply for an NSF Geoscience Program grant to fund expansion of this program and its incorporation into the department’s curriculum. Additionally, the geologic issues to be addressed by this work will be of great interest to the Utah Geological Survey Applied Geology Program and to the City of Provo. We will seek support from these organizations to help pay for student involvement in the program.

**Equipment Needs**

The School of Science and Health is in the process of purchasing the needed high-precision phase-differential GPS surveying equipment, which is the primary equipment need of the project. The department owns computers sufficient for reduction and analysis of the surveying data. Additional needs are tools and supplies for benchmark construction and transportation to surveying sites. Supplemental funding for this equipment is being sought with a proposal for a Scholarly Activities Grant. If this additional funding is not realized, then the needed supplemental equipment will be purchased with departmental funds. Surveying may be aided by collaboration and use of GPS equipment owned by researchers at the University of Utah (David Chapman) and Brigham Young University (Ron Harris).
BIODRAGICAL INFORMATION
Michael P. Bunds
Department of Earth Science
Utah Valley State College

PROFESSIONAL PREPARATION

<table>
<thead>
<tr>
<th>Institution</th>
<th>Field</th>
<th>Degree</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Univ. of California, Santa Barbara</td>
<td>Geological Sciences</td>
<td>B.A.</td>
<td>1984</td>
</tr>
<tr>
<td>University of California, Davis</td>
<td>Geology</td>
<td>M.S.</td>
<td>1994</td>
</tr>
<tr>
<td>University of Utah</td>
<td>Geology</td>
<td>Ph.D.</td>
<td>2001</td>
</tr>
</tbody>
</table>

APPOINTMENTS

<table>
<thead>
<tr>
<th>Position</th>
<th>Institution</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant Professor</td>
<td>Utah Valley State College</td>
<td>1/2000 – present</td>
</tr>
<tr>
<td>Research Intern</td>
<td>Exxon Mobil Upstream Research Company</td>
<td>2000</td>
</tr>
<tr>
<td>Adjunct Instructor</td>
<td>Utah Valley State College</td>
<td>1999 – 2000</td>
</tr>
<tr>
<td>Teaching and Research Assistant</td>
<td>University of Utah</td>
<td>1993 – 1999</td>
</tr>
<tr>
<td>Teaching and Research Assistant</td>
<td>Univ. of California, Davis</td>
<td>1990 – 1993</td>
</tr>
<tr>
<td>Geochemist</td>
<td>USGS Western Minerals Research Branch</td>
<td>1988 - 1990</td>
</tr>
<tr>
<td>Geodetic Surveyor</td>
<td>University of California, Santa Barbara</td>
<td>1982 - 1985</td>
</tr>
</tbody>
</table>

PEER – REVIEWED PUBLICATIONS


Parry, W.T., Bunds, M.P., Bruhn, R.L., Hall, C.M., and Murphy, J.M., 2001, Mineralogy, $^{40}$Ar/$^{39}$Ar dating and apatite fission track dating of rocks along the Castle Mountain fault, Alaska: Tectonophysics, v. 337, p. 149-172.


ABSTRACTS OF PAPERS PRESENTED AT PROFESSIONAL MEETINGS


Roeske, S. M., Snee, L. W., and Bunds, M. P., 1993, $^{40}\text{Ar}/^{39}\text{Ar}$ dates from the Border Ranges fault system, a hydrothermally altered brittle-ductile transition strike-slip shear zone, southern Alaska. GSA Abstracts with programs, 1993 Annual Meeting, vol. 25, no. 5.